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Review Article

Food insecurity and mental health: a systematic review and meta-analysis

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Abstract

Objective: Food security has been suggested to be a risk factor for depression, stress and anxiety. We therefore undertook a systematic review and meta-analysis of available publications to examine these associations further.

Design: Relevant studies were identified by searching Web of Science, Embase, Scopus and PubMed databases up to January 2019.

Setting: OR was pooled using a random-effects model. Standard methods were used for assessment of heterogeneity and publication bias.

Participants: Data were available from nineteen studies with 372 143 individual participants from ten different countries that were pooled for the meta-analysis.

Results: The results showed there was a positive relationship between food insecurity (FI) and risk of depression (OR = 1·40; 95 % CI: 1·30, 1·58) and stress (OR = 1·34; 95 % CI: 1·24, 1·44) but not anxiety. Subgroup analysis by age showed that subjects older than ≥65 years exhibited a higher risk of depression (OR = 1·75; 95 % CI: 1·20, 2·56) than younger participants (OR = 1·34; 95 % CI: 1·20, 1·50), as well as a greater risk of depression in men (OR = 1·42; 95 % CI: 1·17, 1·72) than women (OR = 1·30; 95 % CI: 1·16, 1·46). Finally, subgroup analysis according to geographical location illustrated that food insecure households living in North America had the highest risk of stress and anxiety.

Conclusions: The evidence from this meta-analysis suggests that FI has a significant effect on the likelihood of being stressed or depressed. This indicates that health care services, which alleviate FI, would also promote holistic well-being in adults.

Keywords
Food insecurity
Depression
Stress
Anxiety
Meta-analysis
Anaemia risk
Systematic review

Food security is defined as the assured ability to acquire nutritionally adequate and safe food that meets cultural needs and acquired in a socially acceptable way[1]. Conversely, food insecurity (FI) occurs as a consequence of limited resources and affects many households worldwide, thereby causing malnutrition[2]. Despite considerable progress over the past 25 years in increasing global food production, nearly 795 million people worldwide remain food insecure[3]. In addition, individuals experiencing FI have increased risks of weight abnormalities[4], anaemia[5],

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showing adverse development[6], diabetes[7], hypertension[8], asthma[9] and cancer[10].

FI not only influences nutrition and physical health but may also affect mental health. Consequently, individuals experiencing FI also demonstrate psychological distress including anxiety and depression due to lack of affordable, culturally appropriate food together with an inability to feed both themselves and their families[11]. FI generates uncertainty over the ability to maintain and acquire sufficient food, thereby provoking a stress response that contributes to anxiety and depression[12]. Furthermore, acquiring foods in socially unacceptable ways can induce feelings of alienation, powerlessness, shame and guilt that are associated with depression[13,14]. It also magnifies socioeconomic disparities within households and communities that could increase cultural sensitivities and further adversely influence mental health[15].

A global analysis of FI found that it was associated with poorer mental health and specific psychosocial stressors across different regions[3], which persist after adjusting for confounding demographic and socioeconomic variables[11]. The numerous pathways by which FI may contribute to common mental disorders and the broader social implications of FI linked to cultural norms and self-efficacy may contribute to the cross-cultural consistency of results from previous studies[13,14].

Depression, stress and anxiety are major components of the worldwide burden of disease and play a role in public concern regarding socioeconomic disparities and impacts on the economic burden to society[16]. Depressive disorders are characterised by sadness, loss of interest or pleasure, feelings of guilt or low self-worth, disturbed sleep and/or appetite, feelings of tiredness and poor concentration. Anxiety-related disorders therefore refer to a group of mental disorders characterised by feelings of anxiety and fear[17] and stress as 'a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being'[18]. According to WHO statistics, the total number of people living with depression in the world is ~322 million, and the estimated total number of people living with anxiety disorders is currently ~264 million[19].

To date, observational studies have shown inconsistent effects of FI on depression, stress and anxiety and might not be sufficient to provide concise conclusions. Therefore, a systematic review and meta-analysis was performed to examine the associations between FI and the risk of depression, stress and anxiety.

Methods

Literature search and selection

This meta-analysis was performed in accordance with the guidelines of the 'preferred reporting items for systematic reviews and meta-analyses'[20]. A systematic literature search was undertaken using the Web of Science, Embase, Scopus and PubMed databases from inception up to January 2019. Search strategies used defined subject headings and keywords and did not use language and date restrictions. Our systematic search was conducted by using the relevant search terms (see Supplementary Table 1). The references cited in the retrieved review articles were also searched manually.

Eligibility criteria

Studies were included in the final analysis if they met the following criteria: (i) were observational and reported on the association between FI and depression, stress and anxiety risk and (ii) provided multivariable-adjusted OR with corresponding 95 % CI of FI with depression, stress and anxiety risk. Studies were excluded if: (i) the information could not be extracted; (ii) they were case reports, animal studies, editorials, conference papers, reviews or letters; (iii) they did not report FI as exposure and depression, stress or anxiety risk as an outcome; (iv) participants were under 18 years (i.e. children and adolescents) and (v) they were abstracts with inadequate information and/or dissertations.

Study selection

The titles and abstracts of all articles retrieved in the initial search were evaluated independently by three reviewers. In the next step, following further evaluation of the full texts, articles not meeting the eligibility criteria were excluded by using an online form, with a hierarchical approach based on study design, population or exposure and outcome. The reference lists of relevant review articles identified during this process were also examined to include any additional studies. Full-text articles were retrieved if the citation was considered eligible and subjected to a second evaluation for relevance by the same reviewers. Any disagreements were discussed and resolved by consensus.

Data collection

For all selected studies, two reviewers (SM and AB) extracted data separately using a standard data extraction form. They discussed any discrepancies and sought the assessment of a fourth reviewer (AP) for resolution. Extracted information included relevant study characteristics (name of the first author, year, database, geographical area, study, sample size), population characteristics (age range or mean age, male sex, race/ethnicity), exposure (criteria for, method of FI assessment, level of FI measurement, method of mental health assessment, most fully adjusted OR estimate and the adjusted covariates for calculating OR) and the studies main findings.

Quality assessment for individual studies

Two reviewers (SM and AB) assessed the quality of each selected study using the Newcastle-Ottawa scale (adapted for cross-sectional studies)[21]. This scale awards a maximum

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of ten stars to each study as follows: five stars relate to the selection (representativeness of the sample, sample size, non-respondents and ascertainment of the exposure), two stars to comparability (controls for the effect or factors) and three stars to the features of the outcome (assessment of the outcome and statistical test). High-quality studies were defined as those scoring nine or ten stars. Studies with seven or eight stars were categorised as medium quality, while studies with six stars and below were identified as low quality. The quality score for each study is reported in Table 1. Moreover, the level of agreement between reviewers for data collection as well as for quality assessment was computed by the Kappa statistic or coefficient[22].

Statistical analysis

To analyse the relationship between FI and adult depression, stress and anxiety risk, the fully adjusted risk estimates for depression, stress and anxiety risk were pooled. To accurately examine and explore the possible sources of heterogeneity among studies, subgroup analysis was performed based on age (18–65 and ≥65 years), sex (female, male and mixed), level of FI[23] (mild, moderate and severe) or continent (North America, Europe, Asia and others). Additionally, FI with hunger was considered as severe FI level in the pooling process. Pooled OR (and 95 % CI) was estimated using a weighted random-effect model (the DerSimonian-Laird approach). Heterogeneity among the studies was assessed by Cochran Q and I^2 statistics ($I^2 = (Q\text{-}df)/Q \times 100\,\%$; $I^2 < 25\,\%$, no heterogeneity; $I^2 = 25$–$50\,\%$, moderate heterogeneity; $I^2 = 50$–$75\,\%$, large heterogeneity, $I^2 > 75\,\%$, extreme heterogeneity). The heterogeneity was considered significant if either the Q statistic had $P < 0{\cdot}1$ or $I^2 > 50\,\%$. Begg's test and Egger's test were conducted to evaluate publication bias ($P < 0{\cdot}05$ was considered representative of statistical significance). Also, the trim-and-fill approach was used to obtain an adjusted effect size which took publication bias into account. All statistical tests for this meta-analysis were performed with STATA (version 14.0; Stata Corporation) and the statistical software package IBM SPSS statistics (version 23.0; SPSS, Inc.).

Results

Our systematic literature search produced 2627 publications, after the exclusion of duplicates from the different databases. From these, 2535 publications were excluded because they did not meet study eligibility criteria, leaving ninety-two articles for full-text assessment (Fig. 1). Ultimately, nineteen studies were included in the qualitative synthesis[11,24–42], and they all met the eligibility criteria for the quantitative synthesis[11,24–32,34–42]. Eighteen studies used a cross-sectional approach[11,24–30,32,34–42] and one used a longitudinal approach[31]. The risk ratios of 372 143 individuals in these studies were pooled for the meta-analysis. Sixteen studies[24–26,28–32,34,35,37–42] measured depression risk (n 257 685), seven[11,29,30,34,36,37,41] reported stress risk (n 41 914) and five[27,29,35,37,38] measured anxiety risk (n 89 496). From these, fifteen studies reported their results as maximally adjusted ORs[11,24–30,35–40,42], whilst the four others did not adjust for any covariates[31,32,34,41]. These studies were published between 2007 and 2019 and conducted in the United States[24,25,28,29,36,37,39–41], Mexico[32], New Zealand[11], Canada[27], Malaysia[34], Portugal[38], South Africa[35], France[31], Korea[30,42] and Australia[26]. Table 1 summarises the characteristics of the studies included. Quality assessment of each selected study was assessed using the Newcastle-Ottawa scale and showed that all studies included were of high (n 12) quality[11,25–30,36–39,42] and seven of medium quality[24,31,32,34,35,40,41] (Supplementary Table 2). In addition, our results suggested that the level of agreement between reviewers for data collection as well as for quality assessment was appropriate ($\kappa = 0{\cdot}759$).

Quantitative synthesis

The study-specific, maximally adjusted, ORs results were pooled to examine the associations between FI and the risk of depression, stress and anxiety among adults.

Depression

As shown in Fig. 2 when all ORs were combined with the random-effects model, FI increases the risk of depression among adults (OR = 1·40; 95 % CI: 1·30, 1·58). A high heterogeneity was found amongst studies ($I^2 = 86{\cdot}6\,\%$, $P < 0{\cdot}001$). For detecting the potential sources of heterogeneity, the subgroup analysis was based on age (18–65 and ≥65 years), sex (female, male and mixed), level of FI (mild, moderate and severe) or continent (North America, Europe, Asia) (Table 2). Subgroup analysis by age showed that FI for adults ≥65 years was associated with a higher risk of depression (OR = 1·75; 95 % CI: 1·20, 2·56, $I^2 = 93{\cdot}79\,\%$, $P < 0{\cdot}001$) than in younger participants (i.e. <18–65 years) (OR = 1·34; 95 % CI: 1·20, 1·50, $I^2 = 79{\cdot}0\,\%$, $P < 0{\cdot}001$) (Table 2). Subgroup analysis by sex revealed that FI increased the risk of depression in women (OR = 1·30; 95 % CI: 1·16, 1·46, $I^2 = 40{\cdot}4\,\%$, $P = 0{\cdot}18$) and men (OR = 1·42; 95 % CI: 1·17, 1·72, $I^2 = 0{\cdot}0\,\%$, $P = 0{\cdot}78$) (Table 2). In addition, subgroup analysis demonstrated that risk of depression increased with the magnitude of FI from moderate (OR = 1·45; 95 % CI: 1·40, 1·51, $I^2 = 0{\cdot}0\,\%$, $P = 0{\cdot}65$) or severe (OR = 1·77; 95 % CI: 1·71, 1·83, $I^2 = 0{\cdot}0\,\%$, $P = 0{\cdot}57$) levels but not at a mild level (OR = 1·09; 95 % CI: 0·89, 1·36, $I^2 = 0{\cdot}0\,\%$, $P = 0{\cdot}37$) (Table 2). Finally, subgroup analysis according to continent illustrated that FI increased the risk of depression in studies conducted in North America (OR = 1·38; 95 % CI: 1·28, 1·50, $I^2 = 37{\cdot}7\,\%$, $P = 0{\cdot}12$), Europe (OR = 1·31; 95 % CI: 1·04, 1·64, $I^2 = 31{\cdot}3\,\%$, $P = 0{\cdot}22$) or Asia (OR = 1·44; 95 % CI: 1·04, 2·00, $I^2 = 93{\cdot}7\,\%$, $P < 0{\cdot}001$). Subgroup analysis including sex, level of FI or continent attenuated heterogeneity (Table 2).

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Table 1 Description of the studies included in the meta-analysis

First author	Database/Study design/Country	Subjects: Age(year) Population size Sex	Race/ethnicity	Level of food insecurity measurement	Measure of food insecurity	Mental health assessment	OR (95 % CI)	Main findings	Adjusted variables	Quality score
Kaiser[24]	CWHS/Cross-sectional study/USA	≥18 *n* 4037 (100 % female)	Mixed	Household	FSSM	CWHS forms	Depression risk	Food insecurity increase the depression risk (OR = 1·61; 95 % CI: 1·28, 2·02)	Income as % of federal poverty ratio	+8/10
Johnson[25]	NAFS/Cross-sectional /USA	78·2 ± 8·4 *n* 345	Mixed	Household	USDA	GDS	Depression risk	Food insecurity increase the depression risk (OR = 4·9; 95 % CI: 2·0, 12·0)	Age, sex, race/ethnicity, education, marital status, living arrangement, income, and receive food stamps	+9/10
Carter[11]	SoFIE/Cross-sectional / New Zealand	≥18 *n* 18 955 (8740 male and 10 215 female)	White	Household	SoFIE forms	K-10	Stress risk	Food insecurity increase the stress risk (OR = 1·9; 95 % CI: 1·7, 2·1)	Age, sex, ethnicity, marital status, family composition, household income, labour market activity, level of education, NZ (area) deprivation	+9/10
Ramsey[26]	–/Cross-sectional / Australia	≥20 *n* 505 (44·5 % male and 55·5 % female)	Mixed	Household	FSSM	SF-12	Depression risk	Food insecurity increase the depression risk (OR = 2·89; 95 % CI: 1·29, 4·49)	equivalised household income, indigenous status and household structure	+9/10
Tarasuk[27]	CCHS/Cross-sectional / Canadian	18–64 *n* 77 053	White	Household	FSSM	CCHS	Anxiety risk	Food insecurity increase the anxiety risk (OR = 1·81; 95 % CI: 1·62, 2·03)	Socio-demographic variables	+9/10
Leung[28]	NHANES/Cross-sectional /USA	20–65 *n* 3518	Mixed	Household	FSSM	DSM-IV	Depression risk	Food insecurity increase the depression risk (OR = 1·98; 95 % CI: 1·57, 2·42)	Age, sex, race/ethnicity, education, marital status, household size, poverty level, smoking status and BMI categories	+9/10
Bruening[29]	NIH/Cross-sectional /USA	18·8 ± 0·5 *n* 209 (38 % male and 62 % female)	Mixed	Individual	USDA	ACHAS	Depression, stress and anxiety risk	Food insecurity increase the depression risk (OR = 2·97; 95 % CI: 1·58, 5·60), but not stress risk (OR = 1·42; 95 % CI: 0·77, 2·60) and anxiety risk (OR = 1·49; 95 % CI: 0·99, 6·66)	Sex, age, race/ethnicity, meal plan, Pell grant status, highest parental education and the clustering of students within residence halls	+9/10
Chung[30]	KNHANES/Cross-sectional/Korea	20–64 *n* 5862 (2278 male and 3584 female)	Asian	Household	USDA	DSM-IV	Depression and stress risk	Food insecurity increase the stress risk (OR=1·52; 95 % CI: 1·15, 2·01), but not depression risk (OR = 1·26; 95 % CI: 0·89, 1·78)	Sex, age, income, education, alcohol use, smoking status, physical activity, marital status and recipients of food assistance	+9/10

Table 1 *Continued*

First author	Database/Study design/Country	Subjects: Age(year) Population size Sex	Race/ethnicity	Level of food insecurity measurement	Measure of food insecurity	Mental health assessment	OR (95 % CI)	Main findings	Adjusted variables	Quality score
Pryor[31]	TEMPO/ longitudinal study/France	18–35 *n* 1991 (38 male and 62 % female)	Mixed	Household	USDA	MINI	Depression risk	Food insecurity increase the depression risk (RR = 2·01; 95 % CI: 1·01, 4·02)	Unadjusted	+7/10
Maharaj[35]	–/Cross-sectional/ South Africa	18–75 *n* 335 (178 male and 157 female)	African	Household	12-month Food Security Scale	HSC-25	Depression and anxiety risk	Food insecurity increase the depression risk (OR = 4·51; 95 % CI: 2·01, 10·09) and anxiety risk (OR = 4·52; 95 % CI: 2·09, 9·80)	Sex and age	+8/10
Vilar-Compte[32]	–/Cross-sectional/ Mexico	≥65 *n* 329 (15·2 % male and 84·8 % female)	Hispanic	Household	ELCSA	GDS-5	Depression risk	Food insecurity increase the depression risk (OR = 2·84; 95 % CI: 1·77, 4·54)	Unadjusted	+7/10
Hudin[34]	FELDA/Cross-sectional/ Malaysia	69·7 ± 6·0 *n* 289 (58 male and 238 female)	Asian	Household	Food Security Tool for Elderly (2003)	GDS and DUSOC	Depression and stress risk	Food insecurity increase the depression risk (OR = 11·132; 95 % CI: 5·294, 23·40) and stress risk (OR = 2·47; 95 % CI: 1·18, 5·15)	Unadjusted	+7/10
Tseng[36]	NHIS/Cross-sectional/USA	≥18 *n* 18 456 (8740 male and 10 215 female)	Mixed	Household	USDA	K-6	Stress risk	Food insecurity increase the stress risk (OR = 3·1; 95 % CI: 2·3, 4·0)	Age, race/ethnicity, education, income, health insurance, smoking status, presence of a chronic disease in parent or child, marital status, and employment status	+9/10
Bruening[37]	SPARC/USA	≥18 *n* 1138 (11 261 female; 7195 male)	Mixed	Individual	USDA	ACHAS	Depression, stress and anxiety risk	Food insecurity increase the depression (OR = 1·98; 95 % CI: 1·34, 2·91) and stress risk (OR = 1·69; 95 % CI: 1·16, 2·46), but not anxiety risk (OR = 1·20; 95 % CI: 0·55, 2·59)	Sex, race/ethnicity, Pell grant status and residence hall group	+9/10
Gregorio[38]	EpiDoC/Cross-sectional/ Portugal	≥18 *n* 10 661 (49·64 % female; 50·36 % male)	White	Household	USDA	HRQoL	Depression and anxiety risk	Food insecurity increase the depression risk (OR = 1·50; 95 % CI: 1·09, 2·59) and but not anxiety risk (OR = 0·79; 95 % CI: 0·52, 1·21)	Age group, sex, educational level, employment status and NUTS II	+9/10

Table 1 *Continued*

First author	Database/Study design/Country	Subjects: Age(year) Population size Sex	Race/ethnicity	Level of food insecurity measurement	Measure of food insecurity	Mental health assessment	OR (95 % CI)	Main findings	Adjusted variables	Quality score
Scanlon[39]	–/Cross-sectional/ USA	≥18 *n* 189 (100 % male)	African–American	Household	USDA	CES-D	Depression risk	Food insecurity did not increase the depression risk (OR = 2·36; 95 % CI: 0·89, 6·29)	Age, education, ASPD, depression score and BPD symptom severity score; criminal justice – involvement history, relationship factors	+9/10
Tong[40]	HOPE HOME/ Cross-sectional/ USA	≥50 *n* 350	Mixed	Household	FSSM	CES-D	Depression risk	Food insecurity increase the depression risk (OR = 3·01; 95 % CI: 1·69, 5·38)	Age and education	+8/10
Wattick[41]	–/Cross-sectional/ USA	≥18 *n* 1956	Mixed	Household	USDA	HRQOL	Depression and stress risk	Food insecurity increase the depression (OR = 2·19; 95 % CI: 1·58, 2·79) risk and stress (OR = 2·33; 95 % CI: 1·47, 3·71) risk	Unadjusted	+7/10
Lee[42]	CHS/Cross-sectional/Korea	≥18 *n* 225 965 (65 % female; 49 % male)	Asian	Individual	USDA	CHS	Depression risk	Food insecurity increase the depression risk (RR = 2·33; 95 % CI: 1·47, 3·71)	Sex, residence, chronic disease, drinking status, smoking status, exercise, sleep duration, social network and BMI	+9/10

CWHS, California Women's Health Survey; FSSM, Household Food Security Survey Module; NAFS, Nutrition and Function Study, SoFIE, Survey of Families, Income and Employment; CCHS, Canadian Community Health Survey; ACHAS, American College Health Association survey; KNHANES, Korea National Health and Nutritional Examination Survey; TEMPO, Trajectoires Épidémiologiques en Population; MINI, Mini-International Neuropsychiatric Interview; GDS-5, Geriatric Depression Scale; MHI-5, Mental Health Inventory; PHQ, Patient Health Questionnaire; FIES SM-I, Food Insecurity Experience Scale Survey Module for Individuals; FELDA, Felda Land Development Authority; NHIS, National Health Interview Survey; SPARC, Social impact of Physical Activity and nutRition in College; EpiDoC, Epidemiology of Chronic Diseases Cohort Study; HRQoL, health-related quality of life; CES-D,Centers for Epidemiologic Studies–Depression; CHS, Community Health Survey; ACHAS, American College Health Association survey; HRQOL, health-related quality of life; NEI, Negative Experience Index; and PEI, positive experience index; HSC, Hopkins Symptom Checklist, K-10: Kessler-10 scale.

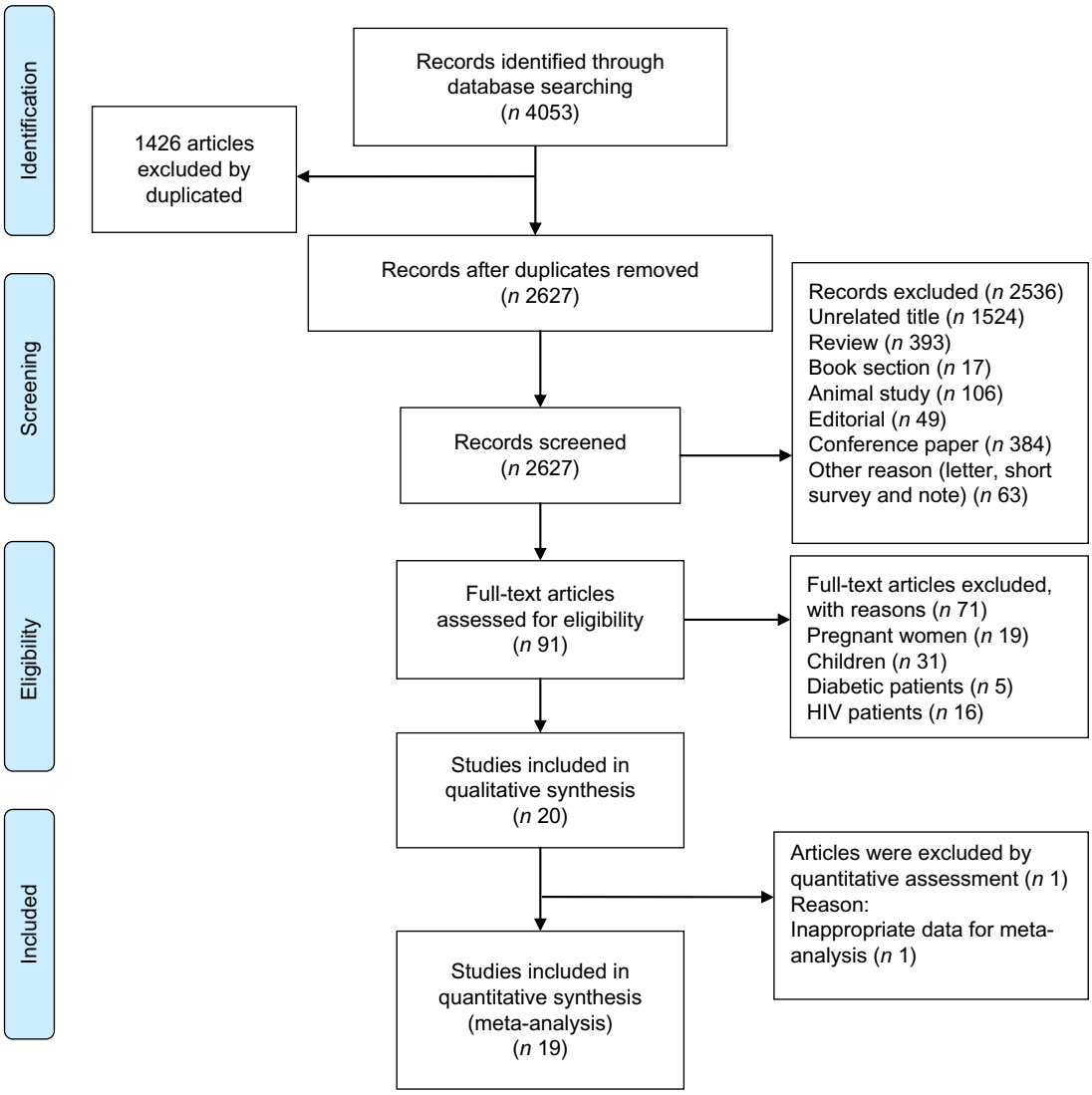

Fig. 1 (colour online) PRISMA flowchart describing the study's systematic literature search and study selection

Stress

As shown in Fig. 3, FI significantly increased the risks of stress in adults (OR = 1·34; 95 % CI: 1·24, 1·44). A moderate heterogeneity was found between studies ($I^2 = 47·3$ %, $P = 0·07$). For detecting the potential sources of heterogeneity, subgroup analysis was run based on the sex (female, male and mixed) and continent (North America and Asia). Subgroup analysis by sex indicated that FI increased the risks of stress among women (OR = 1·41; 95 % CI: 1·33, 1·49, $I^2 = 0·0$, $P = 0·44$) and men (OR = 1·46; 95 % CI: 1·15, 1·85, $I^2 = 83·0$ %, $P = 0·003$) and in both North America (OR = 1·38; 95 % CI: 1·21, 1·57, $I^2 = 52·5$ %, $P = 0·09$) and Asia (OR = 1·26; 95 % CI: 1·06, 1·51, $I^2 = 31·5$ %, $P = 0·22$) (Table 2).

Anxiety

No significant association existed between FI and anxiety risk (OR = 1·22; 95 % CI: 0·98, 1·52). A high heterogeneity was found amongst studies ($I^2 = 80·7$ %, $P < 0·001$) (Fig. 4). However, subgroup analysis based on continent indicated FI increased the risk of anxiety in North America (OR = 1·29; 95 % CI: 1·23, 1·35, $I^2 = 0·0$ %, $P = 0·54$), but not other countries (OR = 1·30; 95 % CI: 0·62, 2·73, $I^2 = 80·7$ %, $P < 0·001$). Subgroup analysis by continent attenuated heterogeneity (Table 2). We did not conduct further subgroup analysis for association between FI and anxiety risk because of the small number of studies.

Sensitivity analysis and publication bias

Sensitivity analysis revealed that the results were not affected by any one study. There was no evidence of publication bias for studies assessing the association between FI, the risk of stress ($P = 1$ for Begg's test and $P = 0·54$ for Egger's test) and anxiety ($P = 1$ for Begg's test and $P = 0·71$ for Egger's test). Although the result from the Begg's test indicated publication bias for studies examining

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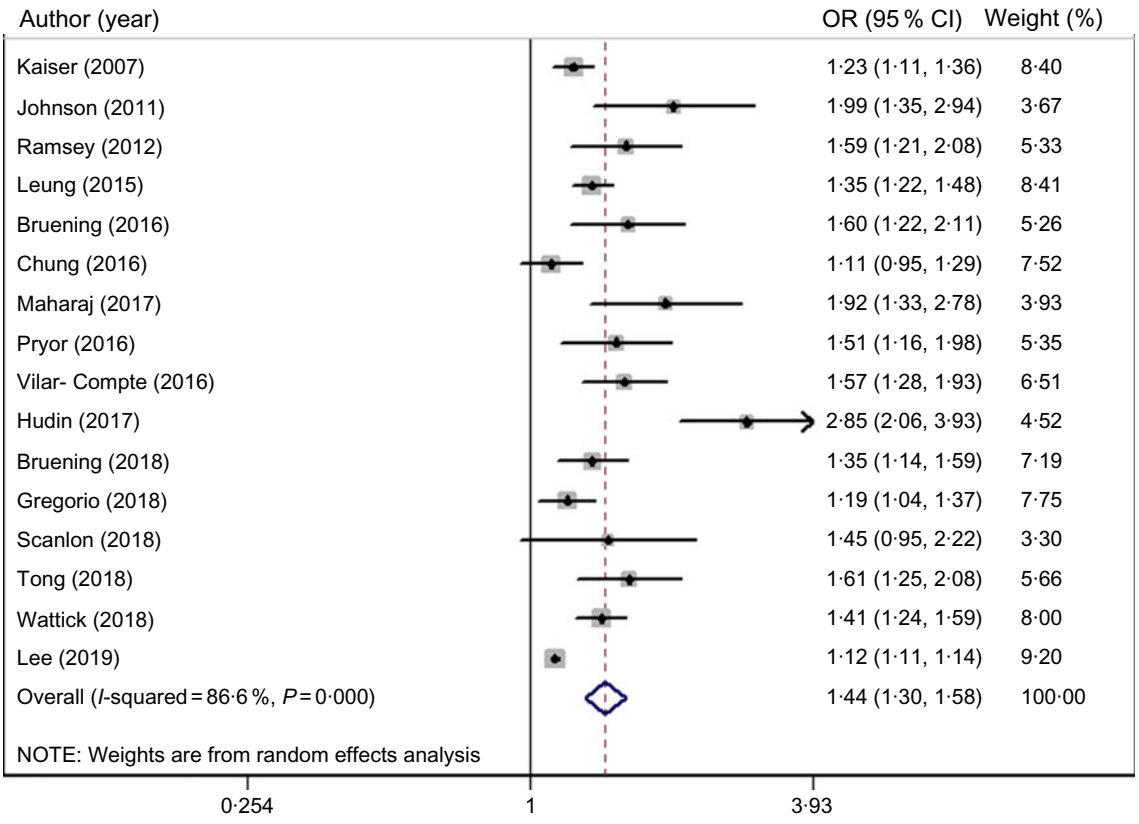

Fig. 2 (colour online) Forest plot showing odds ratio with 95 % confidence interval of the association between food insecurity and depression risk

Table 2 Subgroup analysis to assess the association between food insecurity and mental disorders

Subgrouped by	No. of individuals	No. of studies	OR*	95 % CI	I^2 (%)	*P* for heterogeneity
Depression						
Age (years)						
18–65	30 401	9	1·34	1·20, 1·50	79·0	<0·001
≥65	5730	4	1·75	1·20, 2·56	93·0	<0·001
Sex						
Women	5054	3	1·30	1·16, 1·46	40·4	0·18
Men	1012	3	1·42	1·17, 1·72	0·0	0·78
Mixed	251 503	13	1·48	1·31, 1·66	87·7	<0·001
Food insecurity degree						
Mild	7165	2	1·09	0·89, 1·36	0·0	0·37
Moderate	1419	2	1·45	1·40, 1·51	0·0	0·65
Severe	1377	3	1·77	1·71, 1·83	0·0	0·57
Continent						
North America	11 742	8	1·38	1·28, 1·50	37·7	0·12
Europe	12 652	2	1·31	1·04, 1·64	31·30	0·22
Asia	234 807	3	1·44	1·04, 2·00	93·7	<0·001
Stress						
Sex						
Women	10 475	3	1·41	1·33, 1·49	0·0	0·44
Men	8530	3	1·46	1·15, 1·85	83·0	0·003
Mixed	155 324	5	1·80	1·43, 2·17	59·3	0·04
Continent						
North America	21 768	4	1·38	1·21, 1·57	52·5	0·09
Asia	6151	2	1·26	1·06, 1·51	31·5	0·22
Anxiety						
Continent						
North America	78 500	3	1·29	1·23, 1·35	0·0	0·54
Others	10 996	2	1·30	0·62, 2·73	80·7	<0·001

*Calculated by random-effects model.

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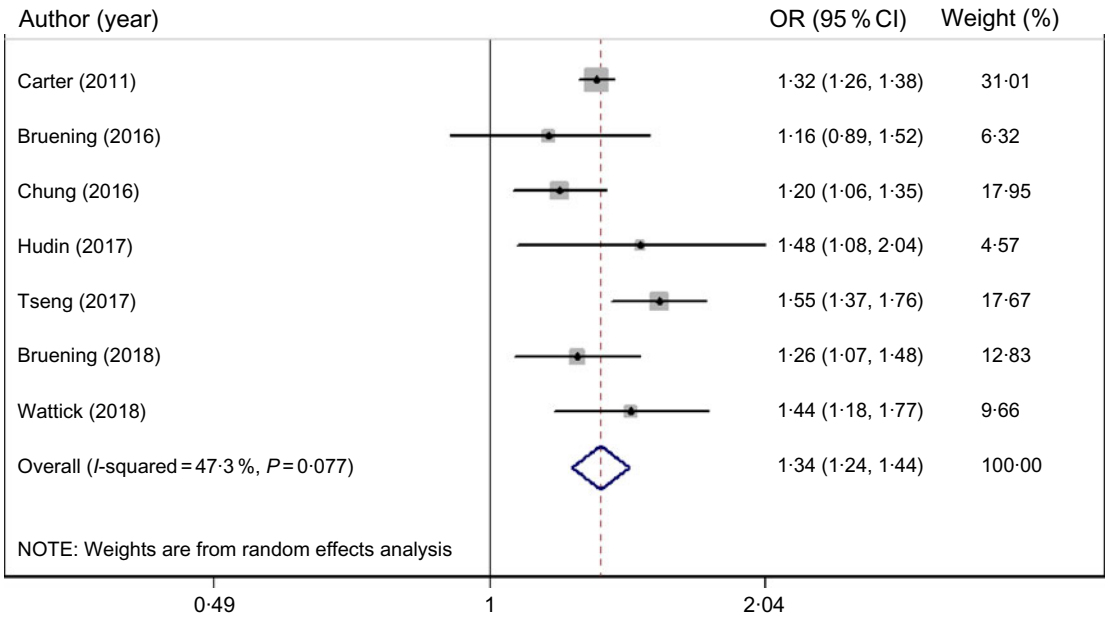

Fig. 3 (colour online) Forest plot showing odds ratio with 95 % confidence interval of the association between food insecurity and stress risk

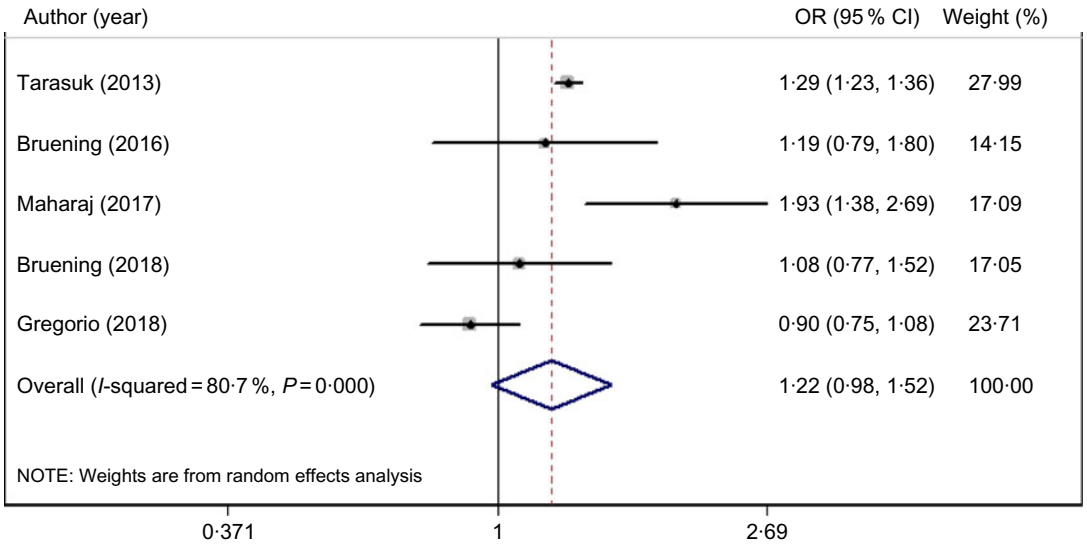

Fig. 4 (colour online) Forest plot showing odds ratio with 95 % confidence interval of the association between food insecurity and anxiety risk

the association between FI and the risk of depression ($P = 0{\cdot}001$), it was not confirmed by the Egger's test ($P = 0{\cdot}24$). The trim-and-fill approach showed that for depression risk is skewed to the right (Supplementary Fig. 1), indicating that six studies with negative results or reverse associations might not have been published (Supplementary Fig. 2).

Discussion

FI has received increasing attention worldwide, with more than 1 billion people estimated to have inadequate access to enough safe and nutritious food to meet their dietary needs for an active and healthy life[43]. Although, the impact of FI on nutritional status, growth and development is well described[44], less is known about the non-nutritional impacts, such as on mental health. Therefore, the purpose of our review was to critically assess the associations between FI and the risks of depression, stress and anxiety among adults in cross-sectional studies. At present, this is the only meta-analysis in this context. The articles we have included illustrate that FI contributes to elevated depression in all subjects especially amongst Asians as well adults aged ≥65 years. It was notable that higher FI increased the risk for depressive symptoms. FI in older people might be

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due several factors including limited financial resources, mobility and transportation. Also, depression can affects ones perception of FI, which is likely to affect responses to FI questions[45].

A simple explanation for the existence of the positive relationship between degree of FI and depressive symptoms is that having insufficient food and nutrients undermines social relationships because of feelings of deprivation and alienation[46]. Consequently, the most severe FI can be found alongside the most depressive symptoms. FI also increased the risk of stress in all subjects, especially those in North America for which, subgroup analysis found that it was associated with increased risk of anxiety. Current findings suggest that this continent might be more strongly related to the onset of psychological disorder risk than others, due in part to the large number of studies from North American (i.e. 9 of 19).

Some mixed findings that were apparent with respect to depression, stress and anxiety, which may depend on publication bias or a sample size effect. More studies were found on depression, compared with anxiety (*n* 5) and stress (*n* 7), and would impact on the statistical power of the meta-analysis. FI is also a broad and complex concept[15], and gathering such data is challenging and can result in measurement errors and misclassifications. In addition, most studies used different assessment tools for FI and mental health. The differences in the adjusted variables included in each study might also affect the results. Moreover, some mediators, such as demographic, socioeconomic, lifestyle and clinical variables, therapy support and genetic background, can all be confounding factors for FI[47,48]. Therefore, these factors might affect any inconsistencies.

Our results for depression and stress were in line with a previous review showing an association between FI and symptoms of common mental disorders[15]. Another review in children indicated that FI was linked to poorer intellectual, behavioural and psycho-emotional development[12], as did a study on women in high-income countries[49].

Pathways linking FI and poor mental health are likely to be both behavioural and biological and mediated centrally as fundamental changes occur in the hippocampus with depression[50]. FI will also contributes to nutrient deficiency[51] and inadequate energy intake[52]. Individuals with FI tend to consume a diet that is high in fat, refined sugars and Na and low in fruit, vegetables and fibre, leading to excess carbohydrate intake and decreased micronutrient consumption[51]. Psychological problems also occur from a diet with a high-energy density and poor nutrient content[4,53] that can lead to overeating when food is readily available and cause adverse metabolic effects[4,54], as well as lower physical activity[4,55] and poor weight management[4,56]. FI also results in an increased psycho-emotional burden by undermining social relationships because of feelings of deprivation and alienation leading to low self-efficacy and a deep sense of helplessness[46]. Even when individuals are consuming adequate food and energy, with FI they may experience anxiety or stress because they are not eating in a culturally unacceptable way[57,58].

Like all studies, ours is not without limitations, which in the case of meta-analysis includes reporting, and personal bias, together with observational biases that could be inherent in the original studies. Although, observational studies make important contributions to the knowledge of the distribution and causes of diseases, possible sources of error and bias include selection, and information bias, measurement errors, plus confounding factors. In addition, it is a snapshot of the population that can change overtime and include Neyman bias (prevalence–incidence bias)[59]. Moreover, the inherent methodologic limitations of cross-sectional studies make it impossible to draw causal links with the variables recorded[59]. Lastly, the studies included different tools used for assessing mental health, and although each of these has their own validity and reliability, the comparability of these measures is an important consideration that should be addressed.

We observed a high percentage of heterogeneity that may be due to the small number of studies (*less than ~10 studies*) for anxiety[60]. Furthermore, we did not undertake an assessment of the grey literature and only worked with studies written in English. We were not able to assess the impact of other potential bias including demographic, lifestyle and clinical variables and genetic background. Due to high heterogeneity, subgroup analyses had to be undertaken, which reduced our statistical power. Despite these limitations, the strength of our study was its sensitivity, subgroup analysis and assessment of age, sex, level of FI with continent on the overall effect sizes, together with the high quality of most studies included. In addition, we tried to minimise any biases in the review process by performing a comprehensive search of the literature and also by conducting and reporting the review by adhering to the PRISMA guidelines. Lastly, the studies included used different tools for assessing FI, notably HFIAS and HFSSM. So, although the different measures of FI each have their own validity and reliability, the comparability of these measures should be studied further.

Implications for practice

The evidence from this meta-analysis suggests that FI has a significant effect on the likelihood of experiencing stress and depression, but not anxiety. Interventions that improve FI may reduce the burden of stress and depression and its subsequent impact on the family and society. However, identifying the direction of causality is important from an applied perspective because if FI precedes poor mental health, then interventions to promote food security could promote mental health. If poor mental health precedes FI, then mental health interventions should might do include information on food security.

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Implications for research

To better understand FI and its association with mental health, future longitudinal studies, with other types of statistical analysis such as structural equation modelling with clearly defined, and validated tools for FI assessment are required. These should be more rigorous, with testable definitions of FI. Indeed, current tools available for measuring FI are subjective, rather limited in scope, with a majority assessing only one dimension (i.e. food access). To more accurately assess the true burden of FI, new tools should be adapted or developed to assess all four dimensions including food access, availability, utilisation and stability over time. Furthermore, assessment of associated variables such as demographic, socioeconomic, lifestyle and clinical variables, as well as differences in therapy would strengthen the assessment of potential pathways determining FI. Although, gathering data on actual nutritional intake is challenging[15], traditional dietary assessment methods (food records, FFQ, 24 h recalls, diet history with interviewer-assisted data collection) or new technology-based dietary assessment methods (web-based and mobile device applications) along with measuring FI are necessary. These could determine whether FI households are consuming diets that differ from food secure households and thus contribute to poor mental health.

Conclusion

In conclusion, this meta-analysis suggested that FI contributes to elevated depression in all subjects, especially amongst Asians and ≥65-year-old adults. It was notable that a higher degree of FI increased the risk for depressive symptoms. Based on our findings, FI also increased the risk of stress in all subjects, especially those in North America. These results indicate that health care services, which alleviate FI, would also promote holistic well-being. Implementing strategies to reduce the risk of mental disorders, especially in food insecure regions, through improving the bioavailability of complementary foods and following dietary guidelines should now be integrated into programmes designed to alleviate poverty. Furthermore, longitudinal and in-depth qualitative studies with longer follow-up periods are warranted to assess the possible relationship between household food security and adult mental health.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S136898001900435X.

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